

Buckling Study: Inner Warm Cylinder (IWC)

Note: This calculation should establish the buckling limit of the IWC; Adequate protection should be used to protect it from excessive over-pressure.

Nomenclature:

Material: Al 5083

E = elastic modulus, MPa

S_y = yield point, MPa

μ = Poisson's ratio

D = diameter of the cylinder, mm

t = thickness of the cylinder, mm

L = length between supports, mm

R = rad of the cylinder, mm

FS = Factor of Safety (Normal)

FSx = Factor of Safety(Exceptional;CODAP)

A = Factor A (ASME BPV Code)

B = Factor B (ASME BPV Code)

P_{cr}* = critical pressure, bar

P_{a*} = allowable pressure, bar (@ FS=3)

P_{a*x} = allowable pressure, bar (@ FS = 2.2)

* <---- Reference no.

Conversion:

$$\text{MPa} := 10^6 \text{ Pa}$$

$$\text{bar} := 10^5 \text{ Pa}$$

Given data:

$$E := 71000 \text{ MPa}$$

$$S_y := 117 \cdot \text{MPa}$$

$$\mu := 0.3$$

$$D := 2306.6 \text{ mm}$$

$$t := 10 \text{ mm}$$

$$L := 6080 \text{ mm}$$

$$FS := 3$$

$$FSx := 2.2$$

$$R := \frac{D}{2}$$

I. Reference:

Theory of Elastic Stability, S. Timoshenko and J. Gere,
Second Edition, Eq. 11-12, p. 478:

$$n := 4 \quad \text{-- value of } n \text{ when } P_{cr1} \text{ is minimum.}$$

$$\text{Let } Z := \left(1 + n^2 \frac{L^2}{\pi^2 \cdot R^2} \right)^2$$

$$P_{cr1} := \frac{(E \cdot t)}{\left[(1 - \mu^2) \cdot R \right]} \cdot \left[\left(1 - \mu^2 \right) \cdot \left[\frac{t^2}{(12 \cdot R^2)} \cdot \left[n^2 - 1 + \left[\frac{(2 \cdot n^2 - 1 - \mu)}{Z} \right] \right] \right] \right]$$

$$P_{cr1} = 0.83 \text{ bar}$$

$$P_{a1} := \frac{P_{cr1}}{FS}$$

$$P_{a1} = 0.277 \text{ bar} \quad \text{-- ASME Allowable}$$

$$P_{a1x} := \frac{P_{cr1}}{FSx} \quad \text{-- CODAP Allowable, exceptional situation}$$

$$P_{a1x} = 0.377 \text{ bar} \quad \text{-- CODAP Allowable, exceptional situation}$$

II. Reference:
Theory and Design Of Pressure Vessels (Harvey):

Critical Buckling Pressure:

$$P_{cr2} := 2.6 \cdot E \cdot \frac{\left(\frac{t}{D}\right)^{2.5}}{\left(\frac{L}{D}\right)} \quad \text{--> Eq. 8.5.13, Theory and Design of Pressure Vessels, 1985, J. Harvey, p.583}$$

$$P_{cr2} = 0.867 \text{ bar}$$

$$P_{a2} := \frac{P_{cr2}}{FS}$$

$$P_{a2} = 0.289 \text{ bar} \quad \text{--> ASME Allowable}$$

$$P_{a2x} := \frac{P_{cr2}}{FS_x} \quad \text{--> CODAP Allowable, exceptional situation}$$

$$P_{a2x} = 0.394 \text{ bar} \quad \text{--> CODAP Allowable, exceptional situation}$$

III. Reference:
Formulas For Stress And Strain (Roark & Young):

Critical Buckling Pressure:

From Table 35, #19b, Formulas For Stress And Strain,
 Roark & Young, 5th Edition:

$$P_{cr3} := 0.807 \cdot \left[E \cdot \frac{t^2}{(L \cdot R)} \right] \cdot \left[\left(\frac{1}{(1 - \mu^2)} \right)^3 \cdot \left(\frac{t}{R} \right)^2 \right]^{0.25}$$

$$P_{cr3} = 0.817 \text{ bar}$$

$$P_{a3} := \frac{P_{cr3}}{FS}$$

$$P_{a3} = 0.272 \text{ bar} \quad \text{--> ASME Allowable}$$

$$P_{a3x} := \frac{P_{cr3}}{FS_x} \quad \text{--> CODAP Allowable, exceptional situation}$$

$$P_{a3x} = 0.371 \text{ bar} \quad \text{--> CODAP Allowable, exceptional situation}$$

IV. Reference:

**ASME Boiler And Pressure Vessel Code, Sec. VIII, Div. I,
Subsection A, Part UG-28: Thickness of Shells and Tubes
Under External Pressure.**

Allowable Buckling Pressure at FS = 3:

$$A := 1.3 \cdot \frac{\left(\frac{t}{D}\right)^{1.5}}{\left(\frac{L}{D}\right)}$$

$$B := A \cdot \frac{E}{2}$$

$$P_{a4} := \frac{\frac{4}{3} \cdot B}{\left(\frac{D}{t}\right)}$$

$$P_{a4} = 0.289 \text{ bar } \text{-- ASME Allowable}$$

$$P_{a4x} := \left(\frac{FS}{FS_x}\right) \cdot P_{a4} \text{ -- CODAP Allowable, exceptional situation}$$

$$P_{a4x} = 0.394 \text{ bar } \text{-- CODAP Allowable, exceptional situation}$$